Original Research Article

Growth and Yield Performance of Some Lowland Rice Varieties Applied with Different Rates of Organic and Inorganic Fertilizers

.

ABSTRACT

Aims: This study was conducted to formulate appropriate fertilization scheme for some rice varieties used at University Income Generating Project (UIGP) sites of Central Mindanao University (CMU) and to determine the effects of organic and inorganic fertilizers on some soil chemical properties.

Study design: Split-plot in Randomized Complete Block Design (RCBD) in three replications with 5 levels of organic and inorganic fertilizers as main plot factor and 3 lowland rice varieties as sub-plot factor.

Place and Duration of Study: UIGP area of CMU, Musuan, Bukidnon, Philippines from November 2015 to April 2016.

Methodology: Plots were laid following Split-plot in RCBD in 3 replications. The 5 fertilizer rates were: no fertilizer, 90-60-60kg NPK /ha, 2t Vermicompost/ha, 45-30-30kg NPK/ha + 2t Vermicompost/ha and 90-60-60kg NPK/ha plus 2t Vermicompost/ha while the three rice varieties were: Matatag 11, NSIC Rc158 and NSIC Rc238. The initial characteristics of the soil served as the basis for the recommended rate of inorganic fertilizer application at 90-60-60 kg NPK/ha.

Results: Results revealed that fertilization rates significantly affected most of the agronomic and yield parameters of rice except the number of days to flowering and 1,000 grain weight. Application of 90-60-60kg NPK/ha + 2t vermicompost/ha exhibited the tallest plants at 30 (P = 0.011) and 50 days after transplanting, DAT (P = 0.006), highest productive tiller count (P = 0.002), percent filled grains (P = 0.026) and grain yield (P = 0.003). Among the varieties, NSIC 238 were the tallest plants at 50DAT (P = 0.006), highest percent filled grains (P = 0.009), earliest to flower (P = 0.001), heaviest 1,000 grain weight (P = 0.009) and grain yield (P = 0.009). There was no interaction effect between fertilization rates and varieties on the agronomic and yield parameters of rice. Moreover, soil pH, organic matter and extractable phosphorus (P) contents of the experimental plots after harvest were significantly influenced by vermicompost and inorganic fertilizer application (P = 0.01).

Conclusion: Findings of the study disclosed that vermicompost can be an effective organic amendment to improve soil pH, soil organic matter content and rice productivity in Maapag soil with NSIC Rc238 rice variety exhibiting promising agronomic parameters and yield components under Musuan conditions.

Keywords: rice, vermicompost, inorganic fertilizers, grain yield, varieties

1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the leading food crops of the world and is produced in all continents. It is the staple food for about 50% of the world's population [1]. The pressure to grow more rice is accelerating due to the increas e of the world's population and the number of expected consumers is still increasing [2]. However, rice productivity and production are constrained by several factors. These constraints include insufficient appropriate technologies, poor cultural management practices of our farmers, which could be due to lack of information and technical skills, fertility of the soil, varietal traits, unreliable water supply, occurrence of pests and diseases and stresses as well [3].

Also, intensified rice mono-cropping and use of high yielding rice varieties that require high application rates of inorganic fertilizers may pose risks to sustainability and productivity of paddy soils [4].

Most rice farms in the Philippines are largely dependent on yield-enhancing technologies such as the use of high yielding varieties and the use of fertilizers. Several farmers are using inorganic fertilizers (to the extent that their concept of high yield for a given cropping season will only be attained using these external inputs) while agricultural wastes are improperly managed and nutrient management strategies are not widely applied in many parts of the country. The use of organic materials such as vermicompost has long been recommended as one of the major remedial measures and is considered as the most practical option for increasing organic inputs in rice production [5] added that vermicomposting is an effective and viable technology for ecological solid waste management and organic agriculture and that nutrients produced by vermiworms depend on the substrate they eat. Also, the use of high yielding varieties with low methane gas emission characteristics are suggested in lowland rice production. Furthermore, sustainable higher crop production cannot be maintained by using inorganic fertilizers alone, nor it is possible to obtain higher crop yields by using only organic manure.

Numerous investigators reported that the crop response to applied fertilizers varies under different soil, climatic and management conditions [6]. Rates of fertilizers which are adequate for a certain yield level in one location could not be the same in another location with different environmental conditions. Hence, this study was conducted under Musuan condition with the general objective of formulating an appropriate fertilization scheme for some rice varieties used at the University Income Generating Project (UIGP) sites of Central Mindanao University and to determine the effects of the organic fertilizer applied alone or in combination with the inorganic fertilizers on the chemical properties of the soil.

2. METHODOLOGY

2.1 Description of experimental site, design and field layout

The soil at the experimental site was mapped as Maapag clay. The soil is strongly acidic with pH value of 5.18. It has marginal organic matter content of only 3.775% [7] which is considered inadequate for rice production. Its extractable phosphorus (P) content of 5.1 mg kg^{-1} is considered deficient and its exchangeable potassium (K) content of only 0.123 cmol kg^{-1} is considered low [8]. Based on results of soil analysis, the fertilizer recommendation of the experimental site is 90-60-60 kg NPK/ha.

The study was conducted following a Split-plot in RCBD in three replications with the 5 levels of organic and inorganic fertilizers as the main plot factor and the 3 lowland rice varieties as the sub-plot factor. The rice varieties and the vermicompost used in the study are those that are currently used and produced by the UIGP of CMU. The treatments and their descriptions are given in Table 1.

Table 1. Treatments and their descriptions

MAINPLOT FACTOR (FERTILIZER)	SUB-PLOT FACTOR (VARIETY)	TREATMENT DESCRIPTIONS
No fertilizer	Matatag 11	No fertilizer; Matatag 11
	NSIC 158	No fertilizer; NSIC 158
	NSIC 238	No fertilizer; NSIC 238
90-60-60	Matatag 11	90-60-60; Matatag 11
	NSIC 158	90-60-60; NSIC 158
	NSIC 238	90-60-60; NSIC 238
2t Vermicompost/ha	Matatag 11	2 tons Vermi; Matatag 11
	NSIC 158	2 tons Vermi; NSIC 158
	NSIC 238	2 tons Vermi; NSIC 238
45-30-30 + 2t Vermicompost/ha	Matatag 11	45-30-30+2t Vermi; Matatag 11
	NSIC 158	45-30-30+2t Vermi; NSIC 158
	NSIC 238	45-30-30+2t Vermi; NSIC 238

90-60-60 + 2t Vermicompost/ha	Matatag 11	90-60-60+2t Vermi; Matatag 11
	NSIC 158	90-60-60+2t Vermi; NSIC 158
	NSIC 238	90-60-60+2t Vermi; NSIC 238

The characteristics of the three lowland rice varieties that are used in this study are given in Table 2.

Table 2. Characteristics of the three rice varieties

VARIETY	HEIGHT (cm)	MATURITY (days)	AVERAGE YIELD (t/ha)	MAXIMUM YIELD (t/ha)	EATING QUALITY
Matatag 11	95	107	5.7	7.6	soft
NSIC 158	94	113	6,.0	8.1	medium
NSIC 238	110	110	6.4	10.6	medium

Source: PhilRice, CMU

2.2 Cultural practices

The experimental area was mechanically and thoroughly cultivated by puddling 3 times using power tiller turtle with a 1 week interval. The field was harrowed and well-leveled. Dikes were constructed around each experimental plot measuring 6 x 5 m.

The seedlings were raised using wetbed method and were transplanted to the experimental plots at the age of 18 days after sowing. The seedlings were transplanted at the rate of 3-5 seedlings per hill with a distance of 20 cm between rows and 20 cm between hills. A wooden marker was used to ensure uniform distance between hills.

All of the required amounts of vermicompost, one-half of the required N inorganic fertilizer and all of P and K inorganic fertilizers were evenly applied into the allocated experimental plots and mixed with the soil prior to the transplanting of rice seedlings. The remaining half of the required amount of N inorganic fertilizer was top dressed at 2 stages; the first topdressing was at tillering stage and the second was at panicle initiation (45 days after transplanting).

First flooding of rice was done when the plants were already strong enough to stand with the water and after 10 days of flooding the water was drained so that the rice can produce more tillers. Irrigation water and drainage was maintained as appropriately and as uniformly in all experimental plots as needed.

Pesticides such as insecticide, molluscide and herbicides were used during pest attacks. These were applied early in the morning at uniform rates in all experimental plots.

Harvesting was done when the rice plants reached maturity. In harvesting, rice plants within the 20 m^2 harvest area were cut close to the ground and were placed in the sacks that were labeled with the treatment number and the block number. These were manually threshed and weights of rice were recorded.

2.3 Data collection

Data collected included the agronomic (plant height and tiller number), yield parameters (number of productive tillers, weight of 1,000 rice grains and grain yield) and soil data before and after harvest (soil pH, organic matter content, extractable phosphorus (P) and exchangeable potassium (K) contents.

<u>2.3.1 Agronomic and yield parameters</u>

Plant height was measured from the base of plant to the tip of the tallest leaf of 10 tagged hills per plot at 30 and 50 days after transplanting (DAT) and the average will be taken.

Number of tillers at 30 and 50DAT were counted from the 10 tagged hills per plot and average was obtained.

Number of productive tillers were determined from the 10 tagged hills per plot at harvest and the average was taken.

Grain yield of rice at 14% moisture content (MC) was obtained from the weight of filled grains from the harvest area of 20 m^2 and converted into tons/ha using the formula:

$$\text{Grain yield (t/ha)} = \frac{\text{Plot yield (kg)}}{20\ m^2} \times \frac{10{,}000\ m^2}{1\ \text{ha}} \times \frac{100 - MC}{86} \times \frac{1\ \text{ton}}{1{,}000\ \text{kg}}$$

2.3.2 Soil data

Analyses of the soil properties were performed at the Soil and Plant Analysis Laboratory using the methods outlined in Table 3.

Table 3. Methods used in the analysis of the chemical and physical properties of soil

PROPERTY	METHODS OF ANALYSIS
Soil pH	Potentiometric method (1:5 soil water ratio) [9]
Organic matter content	Walkley- Black method [10]
Extractable P	Bray P_2 (0.1N HCl + 0.03 N NH_4F) [10]
Exchangeable K	1N NH_4OAc extraction/Flame photometer [10]

2.4 Data analysis

All the data were analyzed using the analysis of variance (ANOVA) for Split Plot in Randomized Complete Block Design (RCBD) with IBM SPSS Statistics 21 software. Honestly Significant Difference Test (HSD) was used at the P = 0.05 level of significance to test the differences among the treatment means.

3. RESULTS AND DISCUSSION

The three rice varieties responded differently to the application of the different rates of inorganic fertilizers and vermicompost application.

3.1 Agronomic parameters of rice

3.1.1 Rice plant height

As shown in Table 4, rice plant height at 30 days after transplanting (DAT) and at 50 DAT were significantly affected by the fertilizer application.

At 30DAT, the tallest rice plants were obtained with the combined application of 90-60-60 kg NPK/ha + 2 tons vermicompost/ha (P = 0.0112). The plants were significantly taller plants compared to those plants of the other treatments. This is attributed to more available nutrients from the applied inorganic fertilizers and vermicompost that would enhance plant growth [11].

Plant height did not differ significantly among the three rice varieties and there was no interaction effect between the application of fertilizers (inorganic fertilizers and vermicompost) and the rice varieties at 30 DAT.

At 50 DAT, tallest plants were also observed in plants applied with the application of 90-60-60 kg NPK/ha + 2 tons vermicompost/ha (P = 0.006). This is however, not significantly taller than those applied with 90-60-60 kg NPK/ha alone and those applied with 45-30-30 kg NPK/ha + 2 tons vermicompost/ha but significantly taller than those with no fertilizer applied and those that were applied with 2 tons of vermicompost/ha alone. The results mainly implied that plant growth is enhanced by the application of vermicompost and inorganic NPK fertilizers that would provide the nutrients essential for plant growth. The vermicompost contains adequate quantities of N, P, K and several micronutrients essential for plant growth.

The three rice varieties significantly differ in plant height with NSIC 238 plants as the tallest and NSIC 158 as the shortest (*P* = 0.006). This conformed to the average plant height shown in Table 2. There was no significant interaction between the fertilizers (inorganic and vermicompost) and the varieties.

3.1.2 Number of days to 50% and 100% flowering

The number of days to 50% and 100% flowering are also shown in Table 3. The number of days to 50% flowering was not significantly affected by the application of inorganic fertilizers and vermicompost but significantly different among varieties *P* = 0.001) with NSIC 238 having the least number of days to 50% flowering and NSIC 158 plants as the latest to flower.

There was an interaction of fertilizers and variety (P = 0.026) with NSIC 238 plants applied with vermicompost alone or in combination with inorganic fertilizers observed as the earliest to flower. Again, this may enhanced by the application of vermicompost and inorganic N fertilizer that would provide the nutrients essential for plant growth.

Table 4. Plant height at 30 and at 50 DAT and number of days to 50% and 100% flowering

TREATMENTS		PLANT HEIGHT† (cm)		NUMBER OF DAYS†	
FERTILIZER	VARIETY	30 DAT	50 DAT	To 50% Flowering	To 100% Flowering
No Fertilizer	Matatag	38.21	46.88	65.33 ab	69.67
	NSIC 158	30.50	43.96	66.33 a	69.00
	NSIC 238	39.37	47.57	65.00 ab	67.33
90-60-60	Matatag	48.98	55.35	66.67 a	70.00
	NSIC 158	47.01	50.47	66.67 a	71.00
	NSIC 238	49.13	57.38	63.67 bc	67.00
2 tons Vermi	Matatag	43.10	50.81	65.33 ab	69.33
	NSIC 158	37.83	46.60	66.33 a	69.00
	NSIC 238	44.61	52.82	62.33 c	67.00
45-30-30+ 2t Vermi	Matatag	46.19	53.49	65.67 ab	69.00
	NSIC 158	45.17	47.55	66.00 ab	69.00
	NSIC 238	48.57	55.47	63.67 bc	66.33
90-60-60 + 2 t Vermi	Matatag	50.67	61.05	65.33 ab	68.33
	NSIC 158	49.31	59.14	66.67 a	71.00
	NSIC 238	54.80	64.45	62.00 c	66.00
P value		1.000	1.0000	0.026	0.135
Fertilizer means					
No fertilizer		36.02 c	46.14 b	66.56	68.67
90-60-60		48.37 b	54.40 ab	65.67	69.33
2 t Vermi/ha		41.85 bc	50.08 b	64.67	68.44
45-30-30 + 2t Vermi/ha		46.65 bc	52.17 ab	65.11	68.11
90-60-60 + 2 t Vermi/ha		51.59 a	61.55 a	64.67	68.44
P value		0.011	0.006	0.068	1.000
Variety Means					
Matatag 11		45.43	53.51 ab	65.67 b	69.27 a
NSIC 158		41.96	49.55 b	66.40 a	69.80 a
NSIC 238		47.30	55.54 a	63.33 c	66.73 b
P value		0.119	0.006	0.001	0.001

† *Values followed by the same letter in a column are not significantly different from each other at 5% level of significance based on HSD Test*

The number of days to 100% flowering significantly differed among the varieties with NSIC 238 flowered earlier than those of Matatag 11 and NSIC 158 (*P* = 0.001) but not with the inorganic fertilizer and vermicompost application. There is no interaction effect between the fertilizers and the varieties.

3.2 Yield parameters of rice

3.2.1 Number of productive tillers

The number of productive tillers was significantly affected by the application of inorganic fertilizers and vermicompost (*P* = 0.002) as shown in Table 5. The highest number of productive tillers was obtained in rice plants applied with 90-60-60 kg NPK/ha + 2 tons vermicompost/ha and the lowest number was in plants that were not applied with any fertilizer. Again, this can be attributed to nutrients supplied by vermicompost in addition to those of the inorganic fertilizers. It was reported that the nutrient balance for N is moderately negative, for P is slightly negative, and for K is highly negative in Bangladesh's soils which can be overcome by the addition of adequate amounts of organic matter to the soil from different sources such as leaf manure and green manure, compost, cowdung, oilcake, crop residues, and other organic wastes [12].

The number of productive tillers did not vary between varieties and there was no interaction between the different rates of fertilizer application and the rice varieties.

3.2.2 Percentage filled grains

The percentage of filled grains was significantly affected by the application of inorganic fertilizers and vermicompost as shown in Table 5 (*P* = 0.0.026). The highest percentage at 91.85% was attained with 90-60-60 kg NPK/ha + 2 tons vermicompost/ha application and the lowest was observed in the rice plants that were not applied with any fertilizers. Application of vermicompost alone, inorganic fertilizers alone and of 45-30-30 kg NPK/ha + 2 tons vermicompost/ha gave comparable percentage of filled grains. Results indicated the important role/function of nutrients in plant nutrition, growth and development. Vermicompost is a nutrient-rich, microbiologically-active organic amendment that results from the interactions between earthworms and microorganisms during the breakdown of organic matter [5].

The varieties differed in the percentage of filled grains (*P* = 0.039) with NSIC 238 rice plants giving the highest percentage of filled grains. Matatag 11 and NSIC 158 had comparable percentage of filled grains. There was no interaction effect between the application of fertilizers and the varieties.

3.2.3 Weight of 1,000 grains

The highest weight of 1,000 grains at 26.80g was obtained with the application of 90-60-60 kg NPK/ha + 2 tons of vermicompost/ha but is not significantly different from the other fertilizer treatments (Table 5). These results conformed to the findings of Oo et al. [13] who studied the effects of different fertilizers management strategies on growth and yield of glutinous rice and Pandey et al. [6] who investigated on the integrated use of organic materials and inorganic fertilizers on lowland rice production.

The weight of 1,000 grains significantly varied among varieties (*P* = 0.009) with NSIC 238 exhibiting the heaviest grains that was significantly higher than that of NSIC 158 but not that of Matatag 11. There was no interaction between the rates of fertilizer application and the varieties.

Table 5. Number of productive tillers, percentage of filled grains and weight of 1,000 grains

TREATMENTS		PRODUCTIVE TILLER COUNT†	% FILLED GRAINS	1,000 GRAIN WEIGHT† (g)
FERTILIZER	VARIETY			

No Fertilizer	Matatag	11.82	74.88	24.58
	NSIC 158	11.65	73.09	23.93
	NSIC 238	12.13	82.32	25.22
90-60-60	Matatag	15.45	89.55	26.92
	NSIC 158	14.97	90.04	24.07
	NSIC 238	16.17	90.64	28.05
2 tons Vermi	Matatag	13.33	83.68	25.01
	NSIC 158	11.98	82.20	24.09
	NSIC 238	13.53	84.90	25.53
45-30-30+ 2t Vermi	Matatag	13.62	88.24	25.83
	NSIC 158	13.83	86.78	24.28
	NSIC 238	14.38	91.88	26.11
90-60-60 + 2 t Vermi	Matatag	19.12	91.10	26.66
	NSIC 158	17.40	91.74	24.38
	NSIC 238	22.32	92.72	29.36
P value		1.000	0.563	1.000
Fertilizer means				
No fertilizer		11.87 c	76.77 c	24.58
90-60-60		15.53 b	90.08 ab	26.35
2 t Vermi/ha		12.95 bc	83.59 bc	24.88
45-30-30 + 2t Vermi/ha		13.94 bc	88.97 ab	25.40
90-60-60 + 2 t Vermi/ha		19.61 a	91.85 a	26.80
P value		0.002	0.026	0.437
Variety Means				
Matatag 11		14.67	85.49 b	25.80 ab
NSIC 158		13.97	84.77 b	24.15 b
NSIC 238		15.71	88.49 a	26.86 a
P value		0.076	0.039	0.009

† *Values followed by the same letter are not significantly different from each other at 5% level of significance based on HSD Test*

3.2.4 Grain yield at 14% moisture content

Rice grain yield was significantly affected by the application of inorganic fertilizers and vermicompost ($P = 0.003$) with the application of 90-60-60 kg NPK/ha + 2 tons vermicompost/ha giving the highest grain yield at 6.36 tons/ha. It was significantly higher than those plants applied with vermicompost alone and those plants that were not applied with any fertilizer but not significantly different from those of plants applied with inorganic fertilizer alone and those of plants applied with 45-30-30 kg NPK/ha + 2 tons vermicompost/ha (Figure 1). This could be attributed to the high solubility of inorganic fertilizers and availability of nutrients for plant use compared to vermicompost. However, long term supply of nutrients to crop plant through inorganic nutrient sources alone degrades soil health and productivity [14] hence, proper management and cultural practices be employed in lowland rice production.

Application of 90-60-60 kg NPK/ha, 2 tons Vermicompost/ha and 45-40-40 kg NPK/ha + 2 tons Vermicompost/ha increased grain yield of rice by 1,26 t/ha, 0.36 t/ha and 1.05 t/ha, respectively but not significantly. However, these increases might be appreciable to the farmers' point of view.

Rice grain yield also varied among varieties. NSIC 238 had the highest grain yield that was significantly higher than that of NSIC 158 ($P = 0.044$) but not that of Matatag 11. There was no interaction observed between the fertilizers application and the variety.

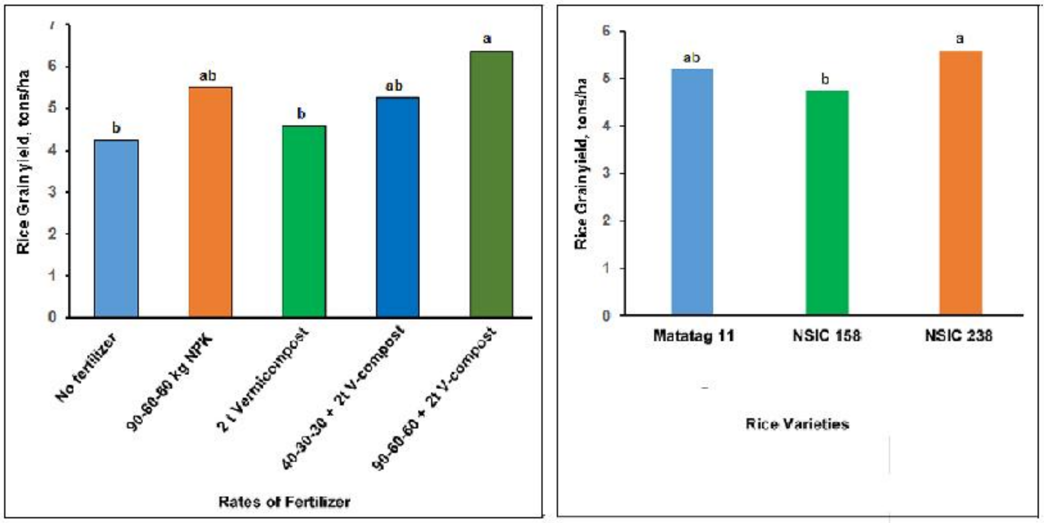

Figure 1. Rice grain yield as affected by the different rates of inorganic and vermicompost application (P = 0.01) and of the varieties (P = 0.05)

3.3 Chemical properties of the soil

The soil pH, organic matter content, extractable P content and the exchangeable K content of the soil after harvest are given in Table 6. The experimental plots that were not fertilized and those that were applied with 90-60-60 kg NPK/ha had significantly lower soil pH values than those applied with vermicompost alone or in combination with the inorganic fertilizers (P = 0.002). Results manifested the acidity effect of inorganic fertilizers on the soil and the improvement of the soil reaction with vermicompost addition.

Similarly, plots applied with vermicompost had higher organic matter contents than those without vermicompost additions (P = 0.004). This would also indicate the organic matter build-up in the soil with vermicompost addition. Conversely, lower extractable P contents were obtained in experimental plots added with vermicompost (P = 0.001) implying the slow release of nutrients from organic materials. The exchangeable K content of the soil was not affected by fertilizer application which indicated that K is not organically bound nutrient. These results corroborated with the results of Oo et al. [13] who investigated the effects of different fertilizers management strategies on growth and yield of upland black glutinous rice and soil properties.

Table 6. Chemical properties of the soil after harvest

TREATMENTS		SOIL pH†	OM CONTENT† (%)	EXTRACTABLE P† (mg kg^{-1})	EXCHANGEABLE K (cmol kg^{-1})
FERTILIZER	VARIETY				
No Fertilizer	Matatag	5.04	3.43	1.92	0.072
	NSIC 158	5.18	4.09	1.27	0.067
	NSIC 238	5.11	4.42	1.13	0.048
90-60-60	Matatag	5.10	3.32	2.60	0.065
	NSIC 158	5.04	4.43	2.72	0.101
	NSIC 238	5.03	3.66	2.05	0.054
2t Vermicompost	Matatag	5.44	5.09	1.30	0.072
	NSIC 158	5.57	5.09	1.23	0.072
	NSIC 238	5.74	4.87	1.20	0.070
45-30-30+ 2t Vermi	Matatag	5.66	4.66	1.05	0.069
	NSIC 158	5.50	4.64	0.81	0.067
	NSIC 238	5.53	4.27	0.64	0.064

90-60-60 + 2t Vermi	Matatag	5.61	5.97	0.69	0.082
	NSIC 158	5.61	5.31	0.70	0.080
	NSIC 238	5.71	5.20	0.64	0.105
P value		1.000	1.000	1.000	0.100
Fertilizer means					
No fertilizer		5.11 b	3.98 bc	1.44 b	0.062
90-60-60		5.06 b	3.80 c	2.46 a	0.073
2 t Vermi/ha		5.58 a	5.01ab	1.24 b	0.071
45-30-30 + 2t Vermi/ha		5.56 a	4.52 abc	0.83 c	0.067
90-60-60 + 2 t Vermi/ha		5.65 a	5.49 a	0.68 c	0.089
P value		0.002	0.004	0.001	0.206
Variety Means					
Matatag 11		5.37	4.49	1.51	0.072
NSIC 158		5.38	4.71	1.34	0.077
NSIC 238		5.42	4.48	1.13	0.068
P value		1.000	1.000	0.092	1.000

† Means followed by the same letter (s) are significantly different from each other at 5% level of significance based on HSD Test

4. CONCLUSION

Results of the study demonstrated that addition of vermicompost as an organic amendment can improve soil pH, soil organic matter, extractable P content of the soil as well as plant growth, grain yield and other yield components of rice.

Application of 90-60-60 kg NPK/ha + 2 tons vermicompost/ha appeared as the most appropriate fertilization scheme for the NSIC 238 rice production under Musuan conditions. However, long-term studies might be needed to verify and ensure reliability of the results and that vermicompost amendment can sustainably improve rice productivity in lowland rice fields.

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